The evaluation of a new iPad Aniseikonia Test

Master thesis

Advised by:
Matjaz Mihelcic M.Sc
Prof.Dr. Anna Nagl

Author: Bc. Michal Krasňanský

This thesis contains no material that has been accepted for the award of any other degree or diploma at any educational institution. To the best author's knowledge and belief it contains no material previously published or written by any other person, except where due reference is made in the text of the thesis.

Bc. Michal Krasňanský

Acknowledgments

I would like to thank my advisors Matjaz Mihelcic M.Sc and Prof.Dr. Anna Nagl for continuous support, advisement, quadience and kind pressure without which I would be never able to finish my studies.

Also many thanks to Essilor Slovakia for providing afocal size lenses for the study and Oculus Slovakia for trims in which the lenses could be mounted. Both of the mentioned firms donated the materials generously.

Content:

Abstract

Purpose

The purpose of this study was to evaluate the validity of the iPad Aniseikonia Test for measurement size lens-induced aniseikonia. The iPad Aniseikonia Test is a new computer-based test designed for measuring aniseikonia in vertical direction. The iPad Test uses red-green anaglyphs.

Methods

Aniseikonia was induced in 21 subjects by means of afocal size lenses. Resulting aniseikonia was measured in vertical direction by the iPad Aniseikonia Test. The measurement was performed in dark condition with appropriate correction of refractive error. All subject were patients with normal vision with no anisometropia or other ocular problem.

Results:

Afocal size lenses of known magnification were used to induce aniseikonia. 5 measurements were taken in each subject, ranging from zero to 7 % magnification. When using the regression analysis, the slope of the fitted line significantly differs from 1. The average slope of regression line is 0,58.

Conclusions:

Only moderate accuracy was found for tested target size and orientation. In all cases the iPad Aniseikonia Test underestimates the level of aniseikonia. However for gross assessment of anisometropia in clinical practice it could be successfully used. Further study with different target size should be addressed.

1 Introduction to Anisometropia and Aniseikonia

1.1 Anisometropia

Anisometropia is a condition with a different refractive error in two eyes. There is no consensus on the exact amount of dioptric difference, which would be diagnosed as anisometropia. Clinically, a difference of 1 diopter (D) in one or more meridians is considered as significant anisometropia. The classification of anisometropia is based on patient's refractive error. Every anisometropia could be classified as one of the following types: compound myopic, compound hyperopic, compound astigmatic, mixed, antimetropic, simple astigmatic, simple myopic, simple hyperopic and vertical.
The adjective "compound" means that both eyes have the same type of refractive error (myopia, hyperopia or astigmatism) but one eye is one diopter more myopic, hyperopic or astigmatic than the other. Astigmatic anisometropia may be easy overlooked in those cases, where the refraction differs in one meridian only (1).

1.2 Incidence and prevalence

The incidence of anisometropia has been studied in various populations. The most common anisometropia, with or without astigmatism, is hyperopic anisometropia (2–4). The prevalence of anisometropia varies significantly. It is mostly due to the absence of universally accepted criteria for anisometropia. The between-eyes dioptric difference, which could be considered as anisometropia, ranges from 1 up to 2 diopters. Some authors consider spherical equivalent only, which may cause underestimation of meridional anisometropia. Study of De Vries (3) reported 4,7% incidence of anisometropia over 2 diopters in sphere or cylinder in child population. The correlation between anisometropia and age in children was also studied. The incidence of anisometropia exceeding 1 D difference was reported to be 1 - 2% in full-term infants' population (5,6). In children of the age of 1 year is the incidence of anisometropia over 1 diopter in spherical or cylindrical power between 2,7 - 11% (4,7). It the Hirsh's study is the anisometropia over 1 D in 6 years old children 2,5 % and in 16 to 19 years old

children 5,6 % (8). Laatikainen and Erkkila (9) reported that 3,6 % of kids between 7 to 15 years show more than 1 diopter difference in spherical equivalent. In Japanese schoolchildren the incidence anisometropia over 1 D was found to be 3,1 % for spherical refractive errors and 4,3 % for astigmatism (10). Phelps and Muir (11) measured anisometropia over 1,5 D in patients from private practices and found the incidence of 3,6 %. In Finland similar study was conducted in normal population aged 5 to 85 years. The incidence of anisometropia of 1,25 - 2 D difference (spherical equivalent) was 4% For anisometropia over 2 D the incidence was 3,1 % (12).

In the Fledelius's study the incidence of anisometropia was evaluated retrospectively in unselected population. His results show the incidence of 9 % (for anisometropia over 1 D), 3,3 % (for anisometropia over 2 D) and 1,5 % for anisometropia over 3 D (2).

The incidence of anisometropia was also studied in Ontario on the American population (13). The incidence of anisometropia over 1 D was found to be 7,24 %.

Several studies fond the increasing rate of anisometropia with age (14–20).

The prevalence of anisometropia has been studied in phakic patients and showed an increase from 10,1 % in patients under 60 years, to 30,8 % in patients older than 80 years (21).

In retrospective study on patients over 85 years, the prevalence of spherical component of anisometropia raised to 42 % and cylindrical component of anisometropia raised to 26 % (16).

The level of anisometropia is associated with refraction error, age and cataract (21).

Moreover, higher incidence of anisometropia was shown in less educated population, which suggests a possible link with intellect (17,20).

Incidence and prevalence of anisometropia was also studied in variously specific populations.

Several studies reported higher incidence of anisometropia over 1D in premature-born infants (5,22,23). In those children the anisometropia is linked to the retinopathy of prematurity, cryo-therapy and younger gestational age (24).

The incidence of anisometropia in premature born kids without retinopathy of prematurity has not to be shown different after 6 months of age(25).

"When premature-born children with the absence of retinopathy reach the age of 6 months, there is no difference in anisometropia incidence compared to the normal age-matched population.

Higher incidence of anisometropia was found in patients with strabismus (11). This is not a surprising finding, as anisometropia is considered as the main factor for strabismus development.

Higher incidence of anisometropia is associated with certain type of ocular pathology. For instance, anisometropia was found predominantly in patients with eye-lid ptosis. In those patients both anisometropia and amblyopia can be found (26,27).

1.3 Progression

The progression of anisometropia during childhood was a subject in several studies. Abrahamson (7) showed, that anisometropia did not significantly change between the age of 1 to 4 years. Nevertheless less than half of children remained anisometropic thorough the whole study. Moreover, he showed that 19 % of children was anisometropic at some point during the study. A relationship is suggested in progression of anisometropia and amount of ametropia. When the refractive error was higher than 3 D (in more ametropic eye) the persistence of anisometropia was 82 % in 4 years old. However, only 25% persistence of anisometropia was found in patients with ametropia less than 3 D (in more ametropic eye). Correspondingly, patients with ametropia between 3,0 - 5,5 D at the age of 1 year, who received the correction in the age of 2,5 years, remained their anisometropia at the age of 5 in 90 % and at the age of 10 in 75 % (28). The amount of anisometropia over 1 D in children over 5 years tends to remain stable after the age of 16 years (8). Similarly, anisometropia (spherical or cylindrical) over 2 D is usually remains stable in school aged children (3).

1.4 Significance

Uncorrected anisometropia may have serious impact on vision. The critical time is during the eye development. The most dangerous type of anisometropia is the compound hyperopia anisometropia. The eye with lower refraction error controls the accommodation for near target. The other eye exerts the same level of accommodation. However due to the higher level of hyperopia, the refraction for near is not sufficient and that eye suffers from blur.

In cases of low ametropia and simple myopic anisometropia (and compound antimetropia) one eye sees clearly near objects, and the other eye sees clearly distant objects.

In cases of higher uncorrected refractive errors (either simple or compound myopic anisometropia), the more ametropic eye does not receive a clear retinal image.

Likewise in cases of uncorrected simple or compound astigmatic anisometropia, neither one nor the other eye receives a clear retinal image.

These conditions may result in further problems with patient's vision such as amblyopia, fusion problems, accommodation problems and focusing difficulties.

1.5 Etiology

The development of anisometropia has most probably a genetic component. However, the trigger for manifestation of this condition is still not clear (29).

Tong and colleagues (30) showed in their study, that anisometropia is caused by a different axial length rather than a difference in corneal dioptric power.

Factors like strabismus or amblyopia are often associated with anisometropia (31). For example, in the Abrahamson's study it was shown, that the onset of strabismus may be followed by anisometropia development (32). The finding was explained by the possible disturbance of the emmetropization process in strabistic eye.

The aforementioned fact supports a study conducted by Smith et al., in which they surgically or optically induced strabismus in monkeys. In this study, 70,8 % of monkeys with surgically induced strabismus and 36 % of monkeys with optically induced strabismus developed also anisometropia. In the control group, the incidence of anisometropia remained significantly lower, at the level of 3 % (33). The finding was explained by the disruption in binocular eye development due to strabismus. This disruption of normal development subsequently caused a different development of the axial length in the two eyes.

Comparable results showed Ingram et al. (34). He noticed higher incidence of anisometropia in children with strabismus. Unilateral ocular pathology has been studied as another cause of anisometropia. For example conditions such as asymmetric nuclear sclerosis, lid pathology, eyelid hemangioma or congenital ptosis occur often together with anisometropia (27,35). Similarly, retinal pathology was widely studied as a cause of anisometropia development. An association between unilateral myopia and previous vitreous or previtreal hemorrhages before the age of 1 year has been documented. In the patients over 2,5 years with the history of a vitreous hemorrhages, but without a damage to the posterior pole, the anisometropia didn't occur.

Moreover, the relationship between the duration of hemorrhage and the rate anisometropia has been found.

With duration longer than 6 months, the mean anisometropia was 7,46 D. With duration shorter than 6 months, the mean anisometropia was 1,96 D (36).

There is also a correlation between anisometropia and retinopathy of prematurity (ROP). A higher risk of anisometropia development was identified in premature infants with ROP compared to premature but non-ROP infants (24,37,38).

Anisometropia can be also caused by other treatment. Wick and Westin showed, that there is significant difference of the amount of anisometropia before and one year after wearing a monovision correction (39). In this study, monovision correction accelerated the progression of anisometropia.

Beside those, certain surgical refractive procedures such as intraocular lens implantation, radial keratotomy or penetrating keratoplasty may result in some amount of anisometropia (40–43).

1.6 Impacts of anisometropia

As it was described above, anisometropia causes problems such as pathological eye development, binocular vision dysfunctions, fusion difficulties and accommodation inability. Anisometropia is also a leading cause of amblyopia.

1.7 Amblyopia

Anisometropia is considered as a primary cause of amblyopia (44). Hyperopic or astigmatic anisometropia of 1 D or higher creates a significant risk of development of amblyopia (45). Anisometropia over 1 D with refractive error over 3 D (in the more ametropic eye) tends to be constant and often leads to amblyopia, when not corrected (46).

In Abrahamsson's studies it was shown, that 30 % of children aged 1 – 4 years with anisometropia over 1 D, and 53 % of children with anisometropia of 3 – 5,5 D became amblyopic (7,28). Similarly, De Vries's study showed the 53% prevalence of amblyopia among anisometropic children with no strabismus or other ocular pathology (3). Another study done by Phelps and Muir found an incidence of amblyopia in anisometropic kids ranging form 47,1 to 59,8 %, depending on age (11).

Moreover, a correlation between the amount of anisometropia and severity of amblyopia is suspected (3,31,47). Early diagnosis of anisometropia is very important and plays a crucial role in preventing amblyopia. There is high probability of developing amblyopia if the patient remains uncorrected after the age of 1 year. Also, patients with higher refractive error (more than 6 D) are at higher risk of developing anisometropic amblyopia (46). The best prevention of anisometropic amblyopia is an early diagnosis of refraction error and prompt correction.

Correction of an anisometropic amblyopia can enhance visual functions both in children and adults (48,49).

1.8 Accommodation

Herring's law of equal innervation causes, that the exerted accommodation effort is almost equal in two eyes. This causes difficulties in cases of the hyperopic anisometropia. As was already mentioned, the eye with lower refraction error leads the accommodation, while the more hyperopic eye receives a blurry image. Fusing two unequal images may result in an accommodative asthenopia (50). Luckily, 60 % of patients with an accommodative asthenopia feel significant relieve simply by wearing the appropriate refractive correction (51).

1.9 Fusion

Patients with anisometropia have to fuse two different images into a single binocular image. In the absence of strabismus, difficulties with sensory fusion can be usually resolved when wearing the right correction (51).

Stereoacuity can be decreased with an anisometropia as low as 0,5 D and 80% of the patients with anisometropia over 1D have difficulties to maintain fusion (52).

Blumenfeld et al. studied the impact of the anisometropia on stereoacuity in patients between 4 and 18 years. The strong negative correlation between the amount of anisometropia and level of stereoacuity was identified. The stereoacuity rapidly decreases in the anisometropia over 1 D (53).

Similarly, an induced anisometropia of 1 D may result in a decrease of stereoacuity (54). In the study performed by Ong and Burely, the same result was found. The depth perception is reduced in patients with anisometropia exceeding 1 D (55).

Anisometropia may be a cause of micro-strabismus and strabismus (56,57). There is also an association between anisometropia and esotropia (45,58).

1.10 Contrast sensitivity

In cases of hyperopic anisometropia, the binocular contrast sensitivity is often found to be lower than monocular contrast sensitivity. It is due to the monocular defocus under binocular conditions (59).

1.11 Signs and symptoms

Anisometropia can cause symptoms such as squinting, frowning, eye rubbing, eye covering, tilting head, headache, asthenopia, photophobia, aniseikonia, and nausea.
In anisometropic presbyopes using spectacles with progressive lenses, diplopia and asthenopia can occur as a consequence of an optical imaging error in lenses. A different prismatic effect is created during a down-gaze through a reading portion of spectacle lens. This different prismatic effect can cause anisophoria and results in asthenopia (41).

2 Assessment of Anisometropia

2.1 Visual acuity

Visual acuity in children is mostly performed with the Preferential-looking cards or the Teller visual acuity cards. The administration of Preferential-looking cards may be more time consuming than the use of Teller cards. However, results obtained by Preferential-looking cards are more precise and reliable. The use of Teller cards may underestimate the level of vision acuity in children and toddlers (60–62).

2.2 Objective refraction

The most valuable tool for measuring objective refraction, particularly in children, is a static (an/or dynamic) retinoscopy. Especially in cases of high refractive errors retinoscopy is a very useful tool to obtain precise results. It is a faster and more reliable method than a subjective refraction.

Automated machines such as autorefractors can be also used. However, in children these may not be suitable due to difficulties with positioning the child behind the machine and poor accommodation control during measurement (63).

2.3 Correction

Hyperopic anisometropia over 1 D, myopic anisometropia over 2 D and astigmatic anisometropia over 1,5 D difference, are significant risk factor for amblyopia development. Mainly in children, a full amount of anisometropia should be prescribed into correction, to prevent conditions such as amblyopia or suppression (64,65). Contact lenses should be considered to prevent an aniseikonia and anisophoria (65). In adults, who have not been fully corrected, the prescription of full correction may be problematic. Adaptation problems may occur. In such a cases, an initial correction should be partial only, when full correction can be reached during several months in a step-like manner (65).

2.4 Side effects of spectacle anisometropic correction

Because accommodation is almost equal between the two eyes, the anisometropia must be corrected in order to obtain a single binocular image. In spectacle lenses correction, various visual disturbances can occur. These disturbances are caused by different prismatic effects, when looking through the peripheral portion of the lens (during a downgaze, upgaze or into sides) (63).

Especially patients, who acquired anisometropia later in life, experience problems with overcoming these visual disturbances (43).

3 Aniseikonia

The word aniseikonia means: “not equal images”. It is defined as a binocular vision condition, in which there is a relative difference in the size and shape of the ocular image between two eyes. A size difference, that causes symptoms, is defined as clinically significant. Smaller amounts of size differences are not clinically significant. Even large amounts of image size do not always cause aniseikonic symptoms in some patients.

The size of each ocular image depends on the retinal image formed by the dioptric systems of the eye, the distribution of retinal receptive elements and physiologic and cortical processes involved in vision. Two ocular images are seldom equal. There are normal differences in image size when two eyes are looking at objects in left or right gaze. The same applies, when objects of interests are in different distance from eyes. These differences form the basis for stereopsis and provide signal for space location.

3.1 History

Aniseikonia has been discussed since late 18th century (66). Aniseikonia as we understand it today, is described in the Clinical Manual of Aniseikonia (67).

An important difference in today understanding of aniseikonia exists. Aniseikonia is not understood as a physical difference of retinal image only, but also as a perceived size difference of images seen by two eyes. The perceived image size difference may differ from the actual physical difference (68–70).

3.2 Types of aniseikonia

We differentiate two types of aniseikonia. Based on the criterion of causation, an aniseikonia is classified as a static and a dynamic aniseikonia (71).

Static aniseikonia is a difference in size of two images, which is not caused by an optical correction. A typical example is a patient with dioptric difference between his two eyes.

Dynamic aniseikonia is induced when the patient is looking through anisometropic optical correction. A patient can suffer from static or dynamic aniseikonia or both (72).

3.3 Incidence

The incidence of aniseikonia differs greatly. The reported varies form 3 % of clinically significant aniseikonia by Dartmouth institute (73), through 20-30 % reported by Duke-Elder (74) to 33 % showed by Burian (75). These differences are caused both by different measurement strategies used in studies and different criteria for aniseikonia.

3.4 Etiology

3.4.1 Optical

Aniseikonia is mostly associated with anisometropia. It is due to the fact, that the anisometropic correction itself causes different image sizes. There are also some rare conditions, when patients without anisometropia may have aniseikonia. This happens when one eye is larger than the other, but has no dioptric error.

In most cases, clinical significant aniseikonia is a dynamic aniseikonia caused by optical elements necessary to correct anisometropia.

Static aniseikonia may be caused by two different factors. First, a difference in axial lengths of the two eyes exists. In this case, the longer eye projects larger image because image is created further on the optical axis.

The second mechanism includes differences in refractive elements in the two eyes (76).

3.4.2 Spacing of optical elements

In cases of axial anisometropia, one eye is larger (longer), than the other. Consequently, the retina in larger eye may be more stretched and photo-receptors have different spatial distribution (68). This is a natural compensation of optical differences between the eyes, which prevents perceiving different image sizes.

However, a differences on retinal level may be caused by various ocular pathology or retinal surgery (77,78).

3.4.3 Cortical nerve fibers

Image sizes created by optical system of the eyes may be influenced by visual system behind retina. Many anisometropes can successfully alternate between spectacle and contact lens correction, which proves certain level of neuroplasticity (76).

3.5 Symptoms

Common symptoms of aniseikonia are asthenopia, headaches, photophobia, reading difficulty, nausea, motility difficulty, nervousness, dizziness, general fatigue and distortion of space (80).

Aniseikonia symptoms	
Symptom	**Frequency [%]**
Asthenopia	67 %
Headache	67 %
Photophobia	27 %
Reading difficulty	23 %
Nausea	15 %
Motility difficulty	11 %
Nervousness	11 %
Dizziness	7 %
General fatigue	7 %
Distortion of space	6 %

Table 1: Aniseikonia symptoms (80)

In the presence of any aforementioned symptoms, the aniseikonia is considered as clinically significant. The clinical approach is based on impact on individual's visual system. Symptoms typically manifest when the sensory adaptation is too low to or the differences in image sizes is too high.

It is noteworthy, that the correction itself may cause another symptoms.

Different opinions exist on the main cause of symptoms. According to Ogle, the crucial cause for asthenopia is the image size difference. Other authors however, consider the anisophoria as a main cause for asthenopia (81).

3.6 Spatial distortion

Aniseikonic patients with a good stereopsis may suffer from spatial distortions (77,79). This effect may be more significant in patients with meridional aniseikonia (82).

3.7 Anisophoria, fusion, eye movements

Anisophoria is a phenomenon, which is often associated with the aniseikonia. In dynamic aniseikonia, the patient looks through optical lens correction of a different strength in the two eyes. Each optical lens creates a prismatic effect when looking through its periphery. In cases of different lens power, different prismatic effect is exerted on the eye pair (82). Accordingly, eye movements itself are an important factor in manifestation of aniseikonia symptoms (72,81).

3.8 Optical features of aniseikonia correction

Spectacle magnification is a ratio of the corrected retinal image size to the uncorrected retinal image size in the eye.

There are two factors, which may influence spectacle magnification – the shape factor and the power factor. The shape factor depends on a front base curve, a thickness of the lens and a refractive index of the lens material. The power factor depends on a vertex distance and a back vertex power.

The formula for spectacle magnification:

$$\mathrm{SM} = \left[\frac{1}{1-\frac{t}{n}\times \mathrm{F1}}\right] \times \left[\frac{1}{1-\mathrm{hFbvp}}\right]$$

Shape factor Power factor

F1- front surface power

n - refractive index of the lens material

t / n- optical thickness of the lens

Fbvp - back vertex power of the lens

h - "stop distance" distance from back surface of the lens to entrance of the pupil

Average distance between corneal vertex and pupil is 3 mm, which means:

h = vertex distance + 3mm

This formula is derivated from basic telescope formulas:

$$\frac{t}{n} = \frac{1}{F1} - \frac{1}{F2}$$

$$M = \frac{-F2}{F1}$$

t/n – optical length of the telescope

F1 – front lens of the telescope

F2 – back lens

M – angular magnification of the telescope

A spectacle lens can be considered as an afocal telescope. Where F1 is the front surface power (base curve), t/n' is the lens thickness, F2 is the back surface power, which (in this case) would make lens afocal lens.

Substituting F2 from previous equation:

$$M = \frac{1}{\frac{\frac{1}{F1} - \frac{t}{n}}{\frac{F1}{1}}}$$

Multiplying the numerator and denominator by 1/F1 yields the shape factor M (shape)

$$M(shape) = \frac{1}{1 - \frac{t}{n} \times F1}$$

(76).

3.8.1 Knapp's law

Knapp's law is a principle, which describes the retinal image size in the corrected ametropia (3).

$$RSM = \frac{1}{1 + gFbvp}$$

g – distance from anterior focal point of the eye to the lens (for the Gullstrand schematic eye 15,7 mm)

RSM – ratio of the corrected retinal image size to the image size of Gullstrand's eye

However, the functional determinant of retinal image size is still discussed. As was mentioned earlier, the actual physical spacing of retinal photoreceptors and the visual cortex interpretation plays a considerable role in the perceived retinal image size (83).

3.9 Diagnosis

Diagnosis of aniseikonia is usually not difficult. The clue is patient's history. Several clinical tests can be performed. Measurements of certain eye dimensions are of particularly importance, such as a corneal curvature or a refractive error.

If corneal curvature and refractive error does not provide enough information, the diagnostic occlusion or aniseikonic clip-on may be used.

The final diagnosis is based on the measurements of perceived image sizes. Various methods can be used for this purpose. Among them most common are the space eikonometer, The Aniseikonia Inspector software, The New Aniseikonia Test or afocal size lenses compensation measurements. Moreover, certain alternative methods can be successfully used, such as a size comparison of two images, alternating cover test, the Turville test and the test with Maddox rod and two point-light sources.

3.9.1 Refractive condition

Patients at the highest risk of aniseikonia are pseudophakic patients, who underwent unilateral cataract extraction, or patients with anisometropia. Otherwise, clinically significant aniseikonia is not a common condition.

3.9.2 Curvature

Differences in the corneal curvature suggest, that certain portion of the present anisometropia is of refractive origin. Consequently, the spectacle correction of such a refractive error may result in aniseikonia.

In case of equal corneal curvatures, the problem with aniseikonia should be milder. However, the aniseikonia cannot be definitely ruled out based on equal corneal curvatures finding. Other differences such as back corneal surface curvature or lens surfaces curvatures may be present.

3.9.3 Size comparison of diplopic images

Comparison of diplopic images is a very effective way how to diagnose aniseikonia. The main advantage is, that no expensive equipment is needed.

It is possible to diagnose horizontal, vertical and overall aniseikonia.

A double vision has to be induced in this method. The patient is wearing appropriate correction all the time. The dissociation can be achieved by inserting a 5Δ lens with its base orientated in the vertical direction.

The patient is asked to compare the perceived size of two images. The ideal target for subjective assessment of both horizontal and vertical aniseikonia is square target. Afocal magnifying size lenses are introduced in front of the eye, which sees smaller image until the image sizes equal. The magnifying power of the size lens, that creates equal images, is the amount of aniseikonia.

In cases meridional aniseikonia, two different size lenses are needed to equalize images. If this is a case, both horizontal and vertical power are measured, and recorded separately.

3.9.4 Alternating cover test

During this test a patient wears appropriate correction and fixes a square target. The examiner occludes eyes alternatively. Patient with aniseikonia reports, that an image of one eye is larger than the image of other eye. Occlusion should be done fast enough (1 second each eye), so the patient would be able to judge the image size. In case of meridional aniseikonia, the patient can focus on the horizontal direction first, and on the vertical direction subsequently. Examiner changes afocal size lenses, until the perceived image size equals. The magnifying power of the size lens, that creates equal images, is the amount of aniseikonia.

3.9.5 The Turville Test

The Turville Test is a method for diagnosing and measuring vertical aniseikonia by using a mechanical septum and size lenses. The patient wears appropriate correction and a septum is placed between patient's eyes, so each eye views it's own target. The patient compares a distance between two horizontal lines. Magnifying afocal size lens is placed in front of that eye, which perceives smaller distance. The magnifying power of the size lens, which creates equal distances, is the amount of aniseikonia (84).

3.9.6 The test with the Maddox rod and two point-light sources

This method is similar to the Size comparison of diplopic images test. Two light sources and the Maddox cylinder are used during this test. The examiner places the Maddox

cylinder in front of one eye, with streaks oriented horizontally. Two light sources are held approximately 20 cm from each other in the distance of 6 meters. The patient judges the distance between two point-light sources and two vertical lines created by the Maddox cylinder. Ideally, both distances (point-to-point and streak-to-streak) should be perceived as the same. Prisms may be used in cases of heterophoria, to help in aligning perceived images. Size lens is placed in front of that eye, which sees smaller distance. The magnifying power of the size lens, which creates equal distances, is the amount of aniseikonia. The same approach is used in vertical meridians, with the Maddox cylinder oriented vertically and light sources held one under another. For the meridional aniseikonia, measurements in both directions are taken separately.

3.9.7 The New Aniseikonia Test

The New Aniseikonia Test consists of the booklet with red-green half circles of different sizes, and red-green glasses. The patient receives an instruction to determine, which of the two half-moons are the same sizes, while wearing red-green glasses. The test is possible to use to determine both horizontal and vertical aniseikonia. However, some authors do not consider this test as precise and useful enough for clinical use (85).

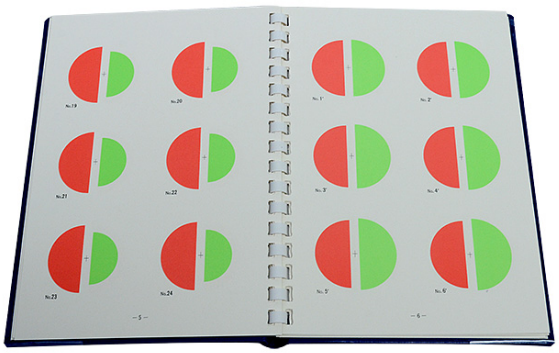


Figure 1: The New Aniseikonia Test

3.9.8 The Aniseikonia Inspector

The Aniseikonia Inspector is a computer based exam tool. A patient wears red-green glasses during testing and directly compares sizes of two red-green images on the computer screen. The patient is instructed to indicate a larger image. The target used in The Aniseikonia Inspector varies depending on the version used. In the original version (Version 1), half circles are used. In the more recent version 2, lines are used as a target. The Aniseikonia Inspector can be successfully used in children (86).

Nonetheless, different studies proved, that The Aniseikonia Inspector tends to underestimate the level of aniseikonia and should be used with caution (87).

Figure 2: The Aniseikonia Inspector testing (88)

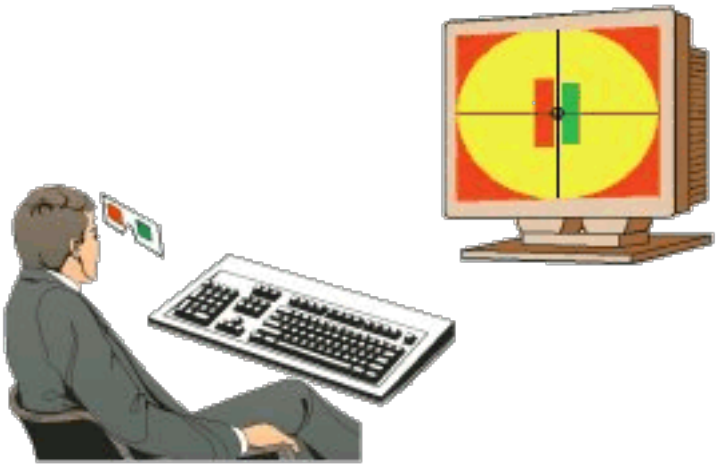


Figure 3: The Aniseikonia Inspector – test set-up (89)

3.9.9 The space eikonometer

The space eikonometer is considered as a precise tool for aniseikonia measurement (85,90). Originally, it was a viewing area of 5 square feet. Later, it was transformed into the table unit with size lenses, which can measure aniseikonia in different meridians (67). With the reduced table-version, aniseikonia can be measured up to 5%

difference only. This reduction limits its usage in measurement of larger aniseikonia. Moreover, the space eikonometer is not commercially available at the moment.

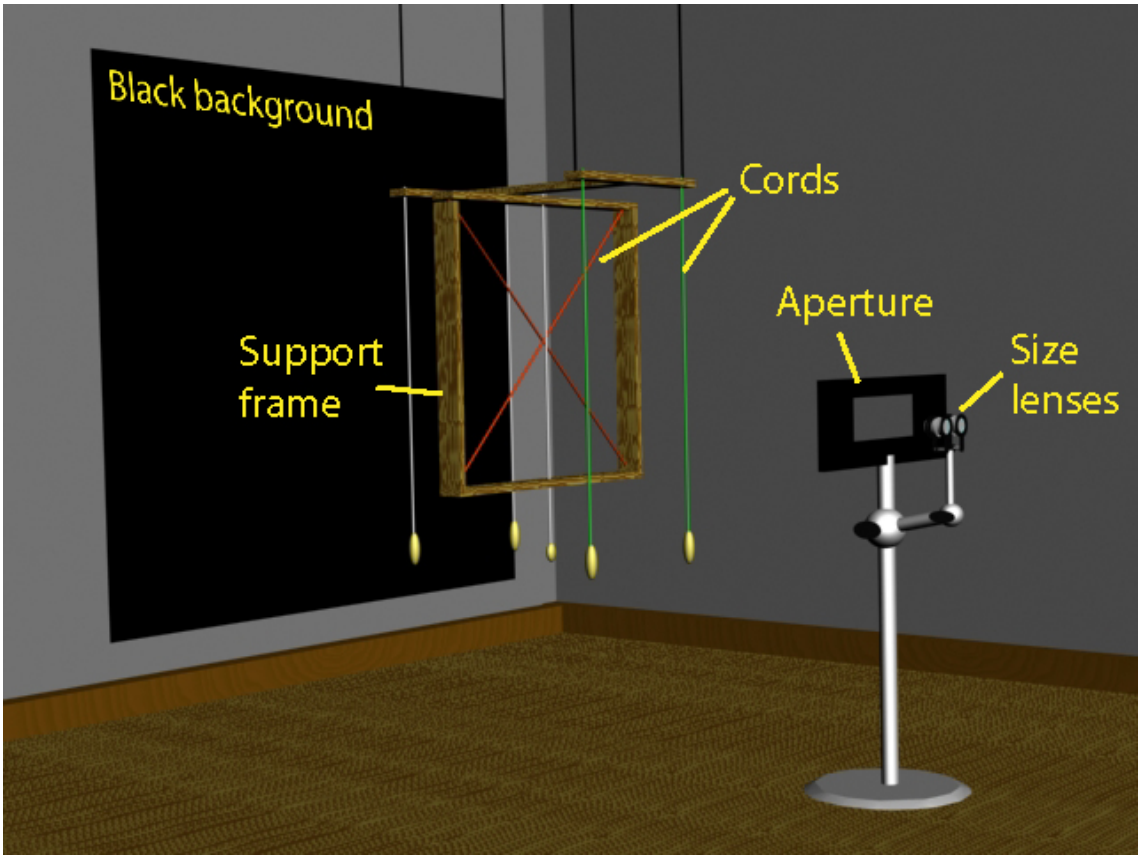


Figure 4: The Space eikonometer scheme (91)

3.9.10 Ocular component analysis

If there is not enough time or equipment for precise aniseikonia measurement, the analysis of optical components may help in diagnosis. The examiner can decide, whether the patient is aniseikonic due to refractive differences between eyes, or because of axial length.

However, the ocular component analysis informs about actual physical image size on the retina only. It is not able to estimate the perceived image size difference. In case of the same or similar difference in keratometric readings and patient's subjective refraction, the most probable is a refractive origin.

An ultrasonography or an optical coherence tomography can be used to measure axial length with high accuracy. This information may be used together with keratometric information for complex diagnosis (76).

3.10 Management

There is not a universally accepted approach to manage aniseikonia. Scheiman and Wick (83) recommends considering various factors, when deciding about aniseikonic correction prescribing. General signs, which warrant a caution, are: inconsistent results during aniseikonia measurements, poor stereopsis, and unexpected orientation of aniseikonia (opposite to what would anisometropia cause). Similarly, if the patient does not report any subjective problems, the aniseikonic correction should be avoided.

On the other hand, patients with consistent results during aniseikonia testing, symptomatic patients, those who feel a relief from symptoms while wearing monocular occlusion, and those experience problems with any other correction, should wear the aniseikonic correction. In those case the special aniseikonic correction would be benefical.

3.10.1 Prescribing options

Prescribing for aniseikonia should be based on subjective methods of aniseikonia testing. When deciding for any correction type, the induced magnification needs to be assessed.

Two main approaches for magnification assessment are: the estimated magnification prescriptions and the measured aniseikonia prescription (92).

Estimated magnification

In estimating magnification, the examiner calculates a relative difference of image sizes created by anisometropic correction. This method is mostly used, when no instrument for measuring aniseikonia is available (92).

Measured aniseikonia prescriptions

The Measured aniseikonia prescription is based on the actual measurement of aniseikonia with any of the methods mentioned previously.

3.10.2 Prescribing lenses for aniseikonia

The process of designing lenses for aniseikonia may be automated. There are companies such as the Shawlens, which specializes in aniseikonia lens design. The company

provides calculation software for designing spectacle lenses (93). If there is no special software provided, the practitioner may design lenses on his own. This process is based on selective changing of the base curve, the central thickness, and the eye wire distance. The purpose is to design a lens with required magnification effect.

Magnification by changing eye wire distance

Modifying the distance between the eye and the spectacle lens may be used to reduce the level of aniseikonia. It can be done by adjusting the frame or during edging process by changing position of the bevel.

Approximate magnification for eye wire distance changes with dioptric powers (see Table 2).

Eye wire distance (h)	**Dioptric power**					
	1D	**2D**	**3D**	**4D**	**5D**	**6D**
1 mm	0,1%	0,2%	0,4%	0,6%	0,8%	1,0%
2 mm	0,2%	0,4%	0,8%	1,2%	1,6%	2,0%
3 mm	0,3%	0,6%	1,2%	1,8%	2,4%	3,0%
4 mm	0,4%	0,8%	1,6%	2,4%	3,2%	4,0%
5 mm	0,5%	1,0%	2,0%	3,0%	4,0%	5,0%

Table 2: Approximate magnification change for eye wire distance (83)

General rule is: When minus lens is moved closer to the eye, magnification increases. When plus lenses are moved closer to the eye, magnification decreases (83).

Magnification by changing base curve

Magnification by changing the front base curve is a useful option how to manage aniseikonic prescription. When the front curve increases, the magnification increases too.

Practitioners need to keep in mind, that with the increase of the base curve, the eye wire distance increases too. This is a desired effect in hyperopia, but certainly not in myopia (83,92).

Magnification by changing lens thickness

The lens magnification increases with an increasing lens thickness. However, with increasing the lens thickness, the edge thickness increases too. The thick lens edge has a negative impact on both the esthetic and weight of future spectacles. On the other hand, wider edge of the lens enables changing the bevel position easily.

Use of bitoric lenses

In cases of meridional aniseikonia, conventional lenses may not help. The eliminating of aniseikonia in one meridian will create a new aniseikonia in a different meridian. Bitoric size lenses change an image size in one meridian. Bitoric lenses are difficult to produce. Even a 0,5 degree misalignment may cause change in a result.

3.10.3 Contact lenses

The first solution in aniseikonia management should be contact lenses, if possible (76).

4 Purpose

The purpose of this study was to inspect the accuracy of the new iPad-based test for aniseikonia measurement. The iPad aniseikonia test consists of a set of digital red-green images (anaglyphs), which are viewed on the iPad screen through red-green glasses.
Measuring the aniseikonia of known magnitude is used for assessment the validity of the test. The aniseikonia was induced by afocal size lenses of five different magnifications (1,5 %, 3 %, 5 % and 7 %) in subject with normal vision.

5 Materials and Subjects

The study was conducted at the clinical setting of the UVEA MEDIKLINK, Martin, Slovakia. 21 patients were included in the study. The age range of the sample was 20 to 59 years, with a mean of 38,5 years.
All subjects were recruited from patients coming for a regular eye examination. The study was performed from the 1.st of July 2015 till 21.st of August 2015. The nature of the study was fully explained and all subjects agreed on participation.
Subjects with amblyopia, anisometropia more than 1 D, fusion problems, cataract, asthenopia, and headaches were excluded. Other exclusion criteria were prior refractive or cataract surgery and binocular vision problems in patients' history. Standardized questionnaire VQS ("Vision Quality Scale", translated in Slovakian language) was administered to each patient prior testing**.** Patients with the score over 15 on the VQS were excluded from the study. Moreover, the ability to see simultaneously both red and green part of the test target was confirmed in each patient.
All the subjects reached corrected visual acuity for the test distance greater than or equal to 1 (20/20). No other ocular disease was revealed during the examination.
The only examiner (the author) performed the complete test routine.

5.1 The iPad Aniseikonia Test

The crucial feature of any aniseikonia testing method is a good image separation. Each eye has to see the appropriate part of test target only, so that a direct comparison of perceived target sizes is enabled.

The iPad Aniseikonia Test was calibrated for the size of the iPad Air screen. The colors of anaglyphic targets were set to match colors of the Oculus red-green filters from trail lens set the OCULUS BK.

Vector drawing application, the Inkpad, was used for drawing of the test figures.

The test target is composed of two red-green brackets on the white background. Due to the subtraction color mixing, the eye with a red filter sees only the green hook, and the eye with a green filter perceives only the red hook. Both eyes perceive a black central cross, which serves as a central fixation stimulus (a fusion lock).

The size of the test figure was 70 mm in a vertical direction and 40 mm in a horizontal direction. The brackets were separated by a white 10 mm space. The whole battery of drowned tests consists of one test with 0% difference in brackets size, and 20 pairs of red-green brackets with a size difference. The sizes of hooks were changed in 1% (0,7 mm) steps in vertical direction only (Figure 5).

The test sequention starts with the red bracket 10% bigger that the green bracket, and ends with red bracket 10% smaller than the green bracket. Every test figure was marked by a number. Number 1 equals red bracket 10% bigger, number 11 equals 0% difference, and number 21 equals red bracket 10% smaller (Table 3). The plus sign before % value means, that red bracket is bigger than green. The 0% means equal size of the images. The minus sign before % value means, that the red bracket is smaller than green.

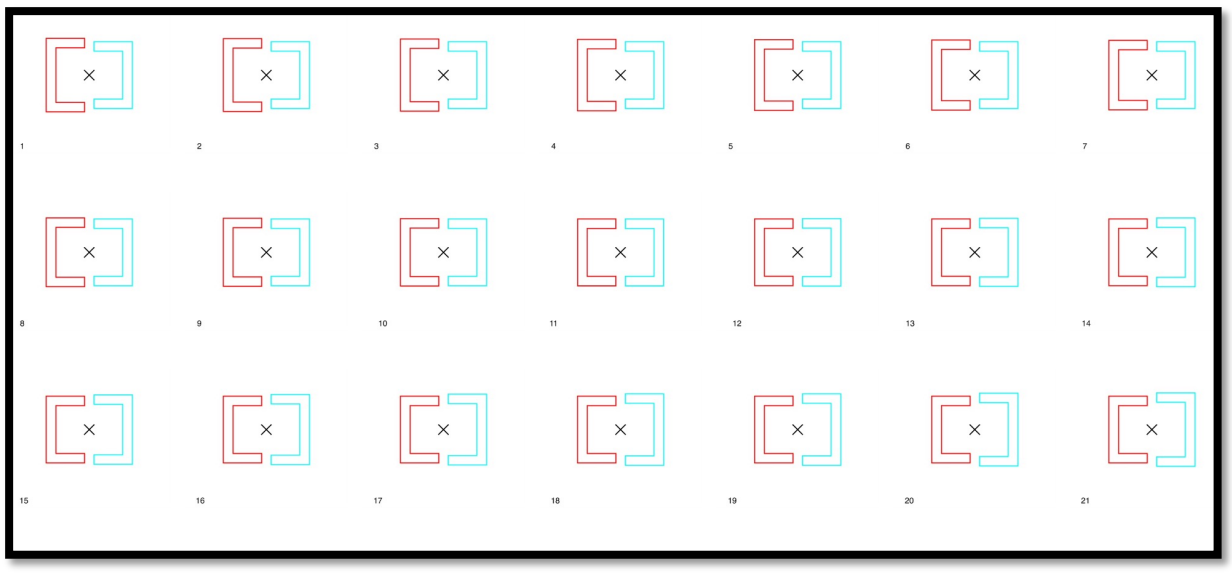


Figure 5: The set of the test targets of different magnification/minification

Aniseikonia Ipad test	
1	10 %
2	9 %
3	8 %
4	7 %
5	6 %
6	5 %
7	4 %
8	3 %
9	2 %
10	1 %
11	0 %
12	-1 %
13	-2 %
14	-3 %
15	-4 %
16	-5 %
17	-6 %
18	-7 %
19	-8 %
20	-9 %
21	-10 %

Table 3:Test numbers and corresponding magnification/minification

5.2 Afocal magnifying size lenses

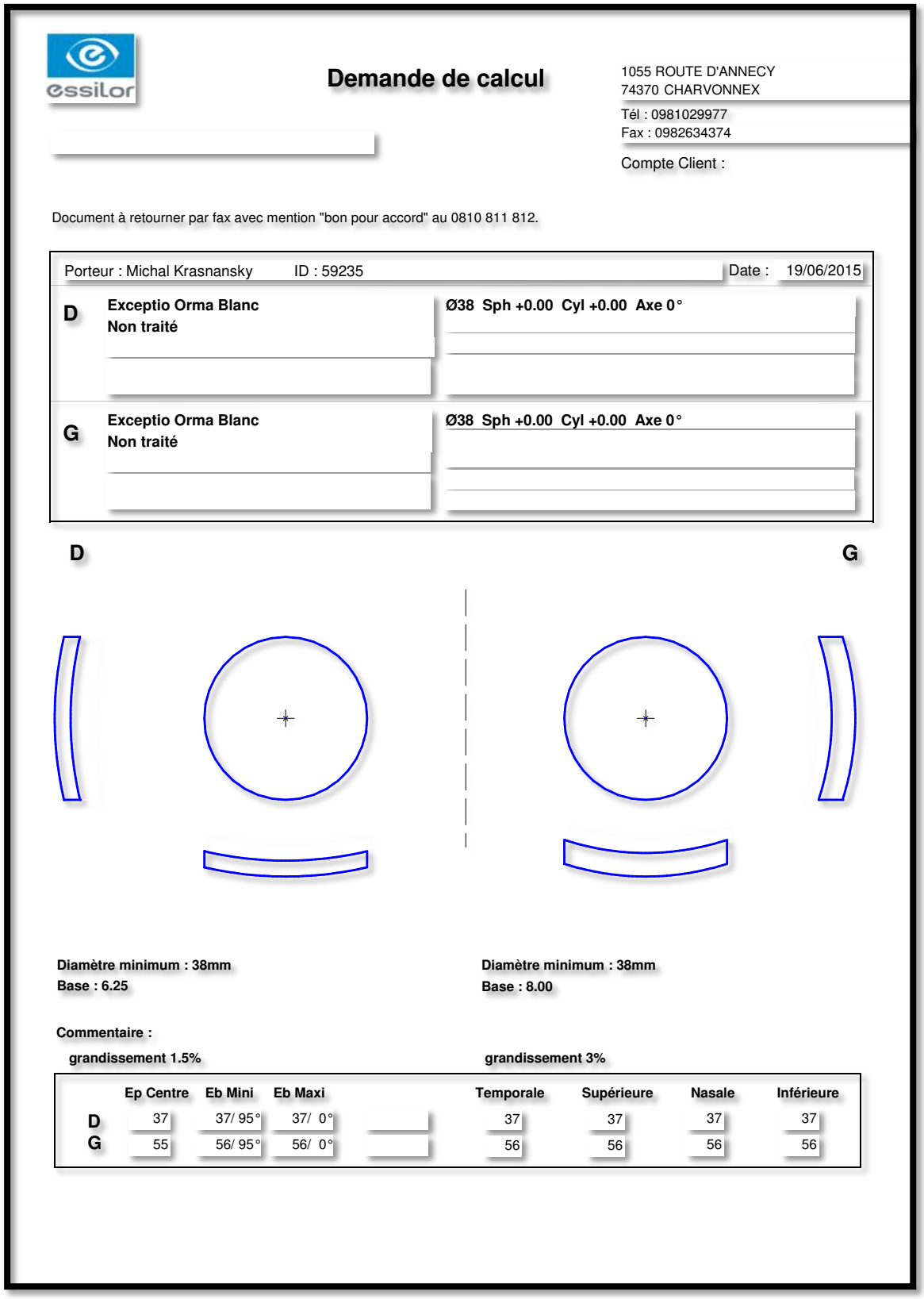
The afocal aniseikonia lenses are currently not commercially available. Still, the aniseikonia measurement with size lenses is considered as a standard. Any new methods are always compared to this method.

For the purpose of this study, the optical company, Essilor Slovakia, donated the afocal size lenses. The 1,5%, 3,0% 5,0%, 7% size lenses were used during the testing. The size lenses were produced in 55mm diameter, calibrated for vertex distance 12 mm and were edged in the Optika UVEA into metal trail rim with the diameter of 38 mm.

The lens parameters specification can be found in the table 4. Figures 6 and 7 shows calculation protocols used for lens manufacturing. Figure 8 depicts the real image of lenses, trimmed into the metal rim.

Magnification	**1,5%**	**3%**	**5%**	**7%**
Refractive index	1,503	1,503	1,503	1,503
Dioptric power	plan	plan	plan	plan
Base curve (diopters)	+5,96	+8,06	+9,00	+10,00
Central thickness (mm)	3,7	5,5	7,0	9,0
Vertex distance (mm)	12	12	12	12
Total magnification	101,5%	103%	104,4%	106,4

Table 4: Size lenses parameters (94)



Demande de calcul

1055 ROUTE D'ANNECY
74370 CHARVONNEX
Tél : 0981029977
Fax : 0982634374
Compte Client :

Document à retourner par fax avec mention "bon pour accord" au 0810 811 812.

Porteur : Michal Krasnansky ID : 59235 Date : 19/06/2015

D	Exceptio Orma Blanc Non traité	Ø38 Sph +0.00 Cyl +0.00 Axe 0°
G	Exceptio Orma Blanc Non traité	Ø38 Sph +0.00 Cyl +0.00 Axe 0°

D G

Diamètre minimum : 38mm
Base : 6.25

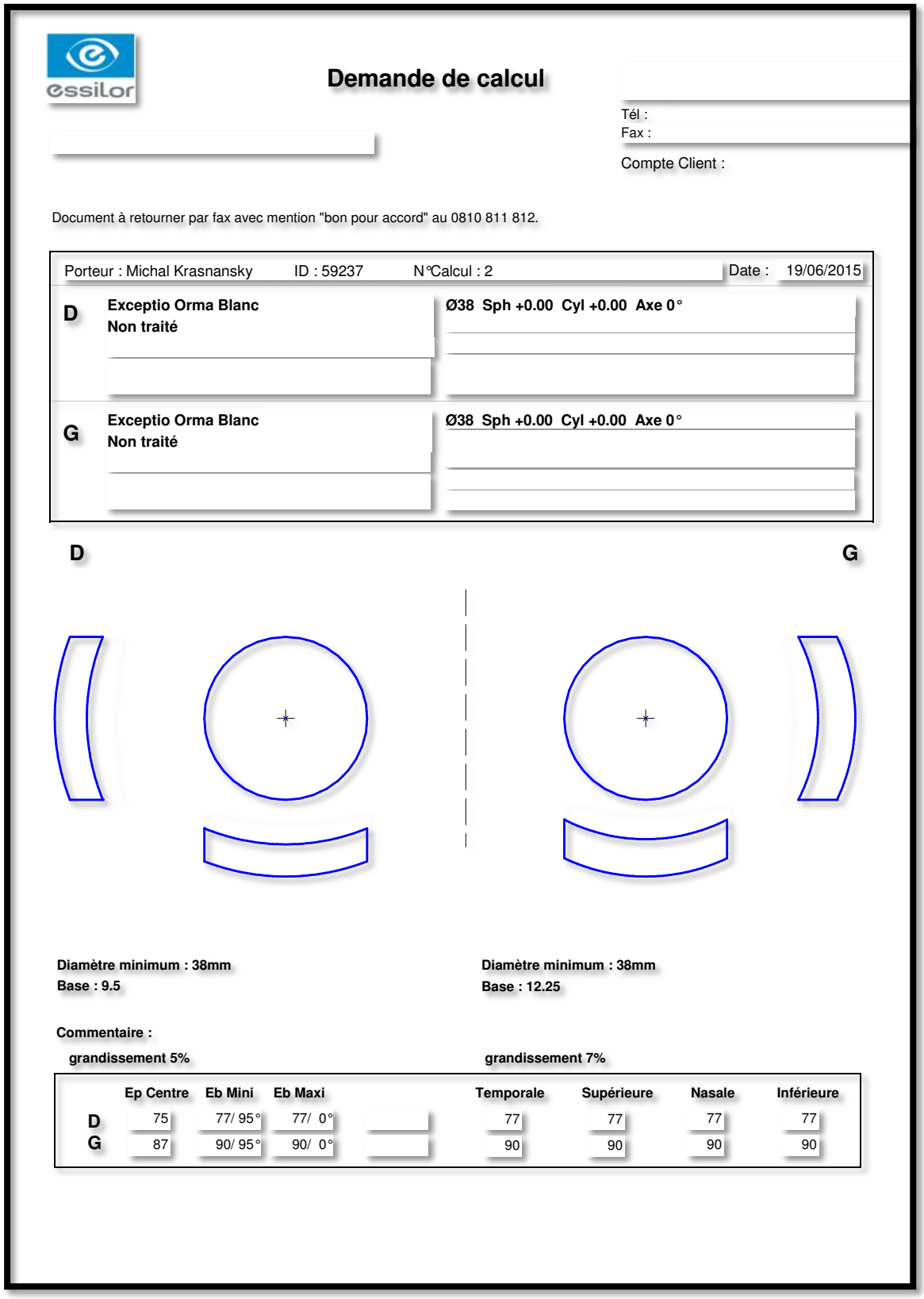
Diamètre minimum : 38mm
Base : 8.00

Commentaire :

grandissement 1.5% grandissement 3%

	Ep Centre	Eb Mini	Eb Maxi		Temporale	Supérieure	Nasale	Inférieure
D	37	37/ 95°	37/ 0°		37	37	37	37
G	55	56/ 95°	56/ 0°		56	56	56	56

Figure 6: Lens calculation protocol (86)



Demande de calcul

Tél :
Fax :
Compte Client :

Document à retourner par fax avec mention "bon pour accord" au 0810 811 812.

Porteur : Michal Krasnansky ID : 59237 N°Calcul : 2 Date : 19/06/2015

D Exceptio Orma Blanc
Non traité
Ø38 Sph +0.00 Cyl +0.00 Axe 0°

G Exceptio Orma Blanc
Non traité
Ø38 Sph +0.00 Cyl +0.00 Axe 0°

D G

Diamètre minimum : 38mm
Base : 9.5

Diamètre minimum : 38mm
Base : 12.25

Commentaire :

grandissement 5% grandissement 7%

	Ep Centre	Eb Mini	Eb Maxi		Temporale	Supérieure	Nasale	Inférieure
D	75	77/ 95°	77/ 0°		77	77	77	77
G	87	90/ 95°	90/ 0°		90	90	90	90

Figure 7: Lens calculation protocol (74)

Figure 8: Size lenses used in study, real view (magnification 1,5 %, 3 %, 5 % and 7 %, from the left)

5.3 Other standard equipment

The Autorefracto-keratometer Topcon KR-1 was used to measure objective refraction and keratometric values in all subjects. The LCD chart projection system Pola Vista Vision, Nidek manual phoroptor, Oculus Trail lens set BK 2, and trail frame Oculus UB-4 were used for subjective refraction.

5.4 Statistical analysis

The statistical analysis was performed on the StatPlus:mac - statistical analysis program for Mac OS. Version v5 (AnalystSoft Inc.).

6 Methods

The aniseikonia testing, in this study, is a subjective examination based on a direct comparison of two dissociated, but simultaneously perceived images. Each patient had to reach adequate vision acuity for testing distance and be absent of any binocular vision problem. For this reason, various measurements were taken before aniseikonia testing.

6.1 Subject history

Initially, patient's history was carefully taken. Every subject was questioned about his subjective problems related to binocular vision. A standardized questionnaire VQS ("Vision Quality Scale") was used to identify patients with abnormal binocular vision. Moreover, subjects with amblyopia, anisometropia over 1 D, fusion problems, cataract, asthenopia, headaches, eye surgery or any other condition, which may have negative influence on tests sensitivity, were excluded from the study.

6.2 Objective measurements

Secondly, subject's objective refraction and keratometric readings were measured using the Topcon auto-refracto-keratometer KR-1. All data were recorded in the exam form.

6.3 Subjective exams

Precise subjective measurement of refraction was necessary to obtain the best-corrected visual acuity. Testing for the test distance was performed too in order to enable the good quality perception of the test target. Patients' response during testing on the iPad Aniseikonia Test is greatly influenced by the ability to see the test target clearly.

For the monocular refraction the manual phoropter (Nidek, Japan) was used. In astigmatic patients, the cylydric power was examined using the Jackson's cross cylinder method. For the final checking of monocular subjective refraction the red-green test was used. In cases when subjects did not respond well on the red-green test, the +1 D blur method was used.

Afterward a binocular vision assessment was performed. For distance dissociated phoria a polarized cross test was used. For distance associated phoria testing, the polarized Mallet test (OXO) was used. Accommodative balance was checked by polarized double line test. Near dissociated phoria was measured on the Thorington scale with the Maddox cylinder. The near associated phoria was measured on the modified Mallet test provided by an iPad Air application "iChart 2000".

When all procedures were done on phoropter, the final subjective refraction was checked by using trail frame. The Humphriss simultaneous contrast method was used to determine final sphere and cylinder axis.

6.4 Aniseikonia testing

Patients wore their appropriate best correction. Red filter was inserted in front of the right eye and green filter in front of the left eye.

The iPad Aniseikonia Test consisted of 21 pictures. For these 21 pictures the separate photo album file was created. The test sequence started with the picture of 10% magnification (red bracket 10% bigger than the green bracket). This difference is large enough for any patient to notice the size difference. Therefore, in the first picture the nature of test was explained.

The iPad was set in full screen mode, so the only visible subjects were the test brackets, the central black fixation cross and the picture number. The picture number was very small and placed in the left lower corner to avoid any impact on perceiving the test target. Patients were instructed to focus on the central cross during the whole testing procedure, and judge the size of two brackets. During the testing, patients were instructed to hold the iPad in reading distance of 40 cm. The distance was checked by the examiner. The test was done in a downgaze position and in low light condition. The examiner showed to patients, how to change tests pictures by swiping the screen from right side to the left side. The instruction was to find the picture with the same sizes of two brackets. Each patient was told the same instruction: "Keep changing the pictures until you find the one, in which the bracket sizes equal!".

Once the patient indicated the selected picture, the examiner recorded the test number.

After testing with no size-lens in place, the testing with size-lenses proceeded. Size lenses were placed in front of right eye in each subject. The order of inserted size lenses was selected randomly. Five different measurements were taken in each patient (no size-lens, 1,5%, 3,0%, 5% and 7% size lens)

7 Results

7.1 General results

A total of 21 patients were examined. In the study sample, there were 8 males and 13 females. The patient's age range was from 20 to 59 years, with the mean of 38,5 years, see table 7. Picture 9 shows the distribution of age in the whole study group.

The age showed to be a significant factor predicting mental and motoric skills when controlling modern digital devices (iPad touch screen).

Table 5: Descriptive statistic of age

Descriptive statistic value	*Age (years)*
Mean	**38,5**
Max	**59**
Min	**20**
STDEV	**11,8**

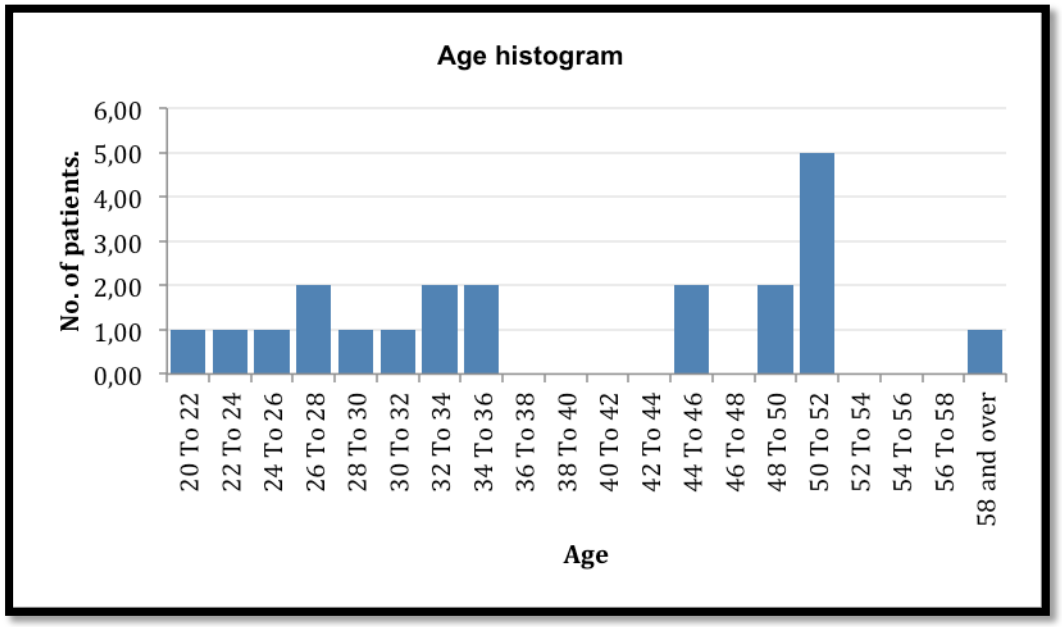


Figure 9: The age histogram

The refraction ranged from sph -4,25 D to sph +2,5 D with a mean of 1,31 D in right eye; and sph -4,50 D to sph +3,00 D with a mean of 1,31 in the left eye. The astigmatism ranged from 0 to -2,75 D of cylinder, with a mean of -0,49 D cylinder in the right eye; and from 0 to -3,5 D with a mean of -0,49 in the left eye.
The average corneal curvature ranged form 7,35 mm to 8,26 mm with a mean of 7,70 in the right eye and from 7,36 mm to 8,32 with a mean of 7,68 mm in the left eye.

7.2 The iPad Aniseikonia Test results

The measurement was taken once with each size lens inserted. The total of 21 patients was measured.

Multiple linear regression method was used for statistical analysis. The aim of this study was to test the validity of The Aniseikonia iPad Test. The magnification perceived on the iPad screen was compared to the absolute magnification induced by the size-lens.

When aniseikonia was induced by the size-lenses of known magnification, the aniseikonia measured on the iPad test consistently showed lower values. The underestimation was quantified by the regression analysis. The slope of the line in a case of an ideal match (the measured level of aniseikonia equals the value of inserted afocal lens) is one. The slope of the fitted line in our experiment is 0,58. This value is significantly different from the ideal slope value of 1.

The underestimation occurred when testing with all afocal size. The most exact results were with testing with no size lens. With increasing level of induced aniseikonia, more underestimation occurred.

The mean value of measure aniseikonia for no inserted size lenses was 0,19 %.

For induced 1,5% of aniseikonia, the mean result was 0,76%.

For induced 3% of aniseikonia, the mean result was 1,76%.

For induced 5% of aniseikonia, the mean result was 2,61%.

For induced 7% of aniseikonia, the mean result was 4,62%.

The individual data are shown in graph 1. The red dots on the graph represent the measured aniseikonia with iPad Aniseikonia Test. The blue line represents the least-squares adjustment of measured data.

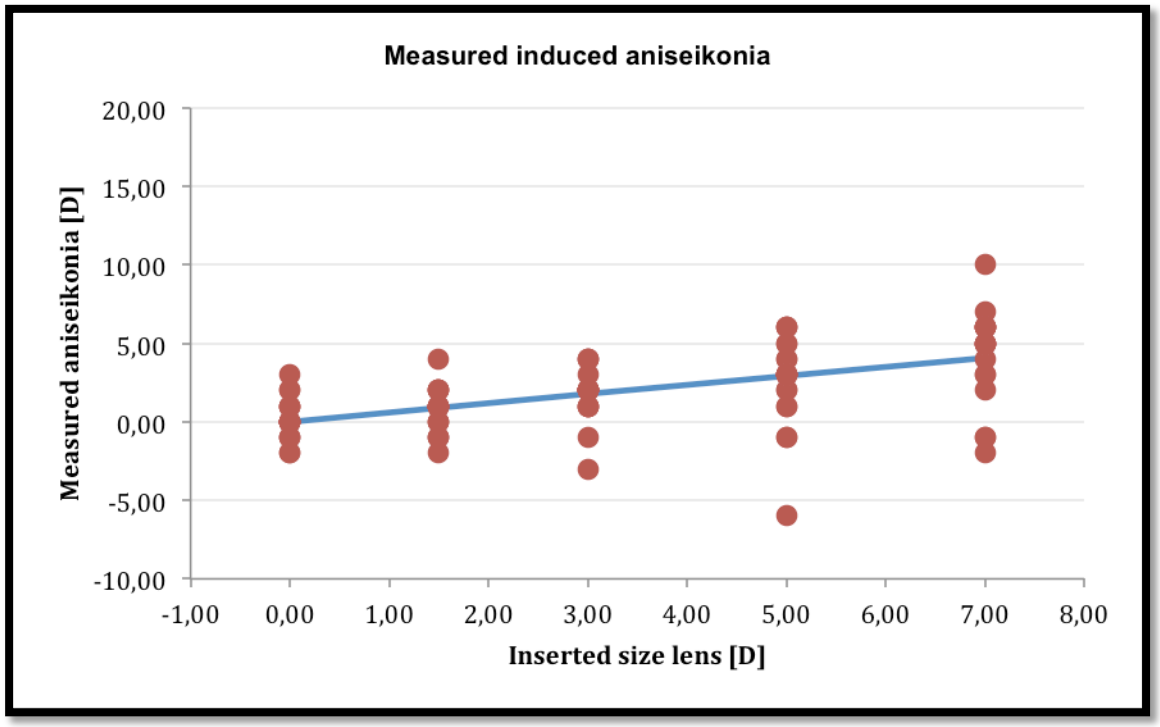


Figure 10: Measured induced aniseikonia for five magnification values

8 Discussion

The purpose of this study was to evaluate the validity of the Ipad Aniseikonia Test for testing induced aniseikonia in normal subjects. 21 normal subjects were tested in total. Afocal size lenses of known magnification were used to induce aniseikonia. 5 measurements were taken in each subject, ranging from zero to 7 % magnification.
When using the regression analysis, the slope of the fitted line significantly differs from 1. The average slope of regression line is 0,58.

In a similar study Antona et. al (87) compares aniseikonia measured with an Aniseikonia Inspector device with the induced level of aniseikonia by afocal lenses. In the Aniseikonia Inspector test the horizontal and vertical aniseikonia are evaluated separately. For vertical aniseikonia he found the mean slope value of 0,93. This was interpreted as an underestimation – same conclusion as in our study, however of dramatically less extend. The reason for this discrepancy may be the range in which he measures the aniseikonia. Antona measured the aniseikonia up to 3% magnification only. In our study we measured the aniseikonia up to 5% and 7% magnification. It was these higher values of magnification where errors in measurement mostly occurred.

This may be caused by the physical thickness of the high magnification size lenses. The afocal lenses of 5% and 7% magnification exhibited large thickness, which prevented them to be inserted in vertex distance of 12 mm as they were calibrated for. Also Antona measured both magnification and minification (up to +3 and -3% size difference). This enabled him to achieve better agreement with expected results.

For the horizontal aniseikonia testing the agreement score was lower even in study of Antona, reaching the regression line slope value of 0,69 only. He discussed the possible influence of horizontal phoria when testing in horizontal direction. The contribution of fusion appeared also in our experiment. Several subjects reported difficulty in size comparison due to the constant target movements. The illumination of the examining room was dimmed to avoid the undesirable fusion response and rescaling, but this still may contribute to final perception.

Similarly de Wit (95) found the slope for regression line of 0,98 in vertical direction. De Wit performed measurements in three directions (horizontal, vertical and oblique) only in 4 patients. The low number of participants however seriously limited the reliability of his study.

The other factor, which influenced our results, is the age and dexterity. Older patients or patients who are not used to control touch screen, had difficulties to control the test. These patients concentrate more for handling the device than for comparing of test figures. Another important factor was that patients predicted the right answer and did not focus on the tests properly. The testing started with 10% size difference so patients had to switch 10 images to get expected value. With 1,5% inserted size lens, the patients had to switch 9-10 images to reach the correct test image. While testing with 5% and 7% size lens, most patients automatically switched first few images (with the expected result) very quickly, with lack of focus. The most inaccurate measurements come from patients with low attention, despite the fact, that they had no problem controlling touch screen.

The shape of the test target may also influence test validity. Corliss et al. (96) compares the performance of two versions of the Aniseikonia Inspector. Those two versions differ in the test target used. In the version 1, the red-green semi-circles are used, while in the version 2 red-green lines are used. The principle in both versions is the same as in our study – direct comparison of anaglyphic images. Corliss tested 27 subjects and concluded, that Aniseikonia Inspector version 2 overestimates aniseikonia by 11,9% in vertical meridian and 11,3 % in horizontal meridian. Oppositely, the

Aniseikonia Inspector version 1 underestimates aniseikonia by 8,8 % in vertical meridian and 8,4 % in horizontal meridian. These large variations in results prove the importance of appropriate test target. As nothing else except of the test target shape was changed, the impact of test target shape is critical. In our study, the bracket test shape was used. It might be this particular test shape, which may negatively influenced our results.

Moreover, significant ametropia was present in patients in our study group. We measured aniseikonia in patients up to -4,5 D. The correcting lenses together with the size lens positioned in a greater distance than which were calibrated for, could result in artifacts in induced level of aniseikonia.

9 Conclusions

Aniseikonia is a serious condition, which can affect quality of live. With an increasing number of patients undergoing unilateral cataract surgery, LASIK, PRK, or other refractive surgery, we need reliable tools for aniseikonia diagnosis. The aniseikonia is more common in elderly patients. The correct diagnosis enables us to make right decisions about refractive management in this still increasing population.

The validity of the new designed iPad Aniseikonia Test has been proved to be of moderate amount only. The aniseikonia was measured in vertical direction only. Further study could examine, if similar or better results would be obtained when testing in horizontal direction. Also, the study group consisted of patients with various level of ametropia but with no anisometropia. The more detailed information could be extracted, if the experiment would be repeated in patients with no refractive error.

Although the underestimation of measured aniseikonia occurred consistently during testing, still the test could be successfully used for aniseikonia diagnosis in symptomatic patients. The level of aniseikonia, which causes symptoms usually, exceeds 5 %. When knowing the tendency of underestimation by 2-3 %, the symptomatic patients still could be identified.

The iPad Aniseikonia Test in its version described here should be used with caution. A further study with different target size, design, orientation and differentiated study population should be addressed.

10 References

1. Cline D, Hofstetter HW, Griffin JR, editors. In: Dictionary of visual science. 4th ed. Radnor, Pa: Chilton; 1989. p. 36.

2. Fledelius HC. Prevalences of astigmatism and anisometropia in adult danes. With reference to presbyopes' possible use of supermarket standard glasses. Acta Ophthalmol (Copenh). 1984 Jun;62(3):391–400.

3. De Vries J. Anisometropia in children: analysis of a hospital population. Br J Ophthalmol. 1985 Jul;69(7):504–7.

4. Ingram RM. Refraction of 1-year-old children after atropine cycloplegia. Br J Ophthalmol. 1979 May;63(5):343–7.

5. Dobson V, Fulton AB, Manning K, Salem D, Petersen RA. Cycloplegic refractions of premature infants. Am J Ophthalmol. 1981 Apr;91(4):490–5.

6. Fulton AB, Dobson V, Salem D, Mar C, Petersen RA, Hansen RM. Cycloplegic refractions in infants and young children. Am J Ophthalmol. 1980 Aug;90(2):239–47.

7. Abrahamsson M, Fabian G, Sjöstrand J. A longitudinal study of a population based sample of astigmatic children. II. The changeability of anisometropia. Acta Ophthalmol (Copenh). 1990 Aug;68(4):435–40.

8. Hirsch MJ. Anisometropia: a preliminary report of the Ojai Longitudinal Study. Am J Optom Arch Am Acad Optom. 1967 Sep;44(9):581–5.

9. Laatikainen L, Erkkilä H. Refractive errors and other ocular findings in school children. Acta Ophthalmol (Copenh). 1980;58(1):129–36.

10. Yamashita T, Watanabe S, Ohba N. A longitudinal study of cycloplegic refraction in a cohort of 350 Japanese schoolchildren. Anisometropia. Ophthalmic Physiol Opt J Br Coll Ophthalmic Opt Optom. 1999 Jan;19(1):30–3.

11. Phelps WL, Muir J. Anisometropia and strabismus. Am Orthopt J. 1977;27:131–3.

12. Aine E. Refractive errors in a Finnish rural population. Acta Ophthalmol (Copenh). 1984 Dec;62(6):944–54.

13. Woodruff ME, Samek MJ. A study of the prevalence of spherical equivalent refractive states and anisometropia in Amerind populations in Ontario. Can J Public Health Rev Can Santé Publique. 1977 Oct;68(5):414–24.

14. Attebo K, Ivers RQ, Mitchell P. Refractive errors in an older population: the Blue Mountains Eye Study. Ophthalmology. 1999 Jun;106(6):1066–72.

15. Wong TY, Foster PJ, Hee J, Ng TP, Tielsch JM, Chew SJ, et al. Prevalence and risk factors for refractive errors in adult Chinese in Singapore. Invest Ophthalmol Vis Sci. 2000 Aug;41(9):2486–94.

16. Haegerstrom-Portnoy G, Schneck ME, Brabyn JA, Lott LA. Development of refractive errors into old age. Optom Vis Sci Off Publ Am Acad Optom. 2002 Oct;79(10):643–9.

17. Saw S-M, Gazzard G, Koh D, Farook M, Widjaja D, Lee J, et al. Prevalence rates of refractive errors in Sumatra, Indonesia. Invest Ophthalmol Vis Sci. 2002 Oct;43(10):3174–80.

18. Cheng C-Y, Hsu W-M, Liu J-H, Tsai S-Y, Chou P. Refractive errors in an elderly Chinese population in Taiwan: the Shihpai Eye Study. Invest Ophthalmol Vis Sci. 2003 Nov;44(11):4630–8.

19. Weale RA. Epidemiology of refractive errors and presbyopia. Surv Ophthalmol. 2003 Oct;48(5):515–43.

20. Bourne RRA, Dineen BP, Ali SM, Noorul Huq DM, Johnson GJ. Prevalence of refractive error in Bangladeshi adults: results of the National Blindness and Low Vision Survey of Bangladesh. Ophthalmology. 2004 Jun;111(6):1150–60.

21. Guzowski M, Fraser-Bell S, Rochtchina E, Wang JJ, Mitchell P. Asymmetric refraction in an older population: the Blue Mountains Eye Study. Am J Ophthalmol. 2003 Sep;136(3):551–3.

22. Graham MV, Gray OP. Refraction of premature babies' eyes. Br Med J. 1963 Jun 1;1(5343):1452–4.

23. Larsson EK, Rydberg AC, Holmström GE. A population-based study of the refractive outcome in 10-year-old preterm and full-term children. Arch Ophthalmol Chic Ill 1960. 2003 Oct;121(10):1430–6.

24. Holmström M, el Azazi M, Kugelberg U. Ophthalmological long-term follow up of preterm infants: a population based, prospective study of the refraction and its development. Br J Ophthalmol. 1998 Nov;82(11):1265–71.

25. Saunders KJ, McCulloch DL, Shepherd AJ, Wilkinson AG. Emmetropisation following preterm birth. Br J Ophthalmol. 2002 Sep;86(9):1035–40.

26. Merriam WW, Ellis FD, Helveston EM. Congenital blepharoptosis, anisometropia, and amblyopia. Am J Ophthalmol. 1980 Mar;89(3):401–7.

27. Beneish R, Williams F, Polomeno RC, Little JM, Ramsey B. Unilateral congenital ptosis and amblyopia. Can J Ophthalmol J Can Ophtalmol. 1983 Apr;18(3):127–30.

28. Abrahamsson M, Sjöstrand J. Natural history of infantile anisometropia. Br J Ophthalmol. 1996 Oct;80(10):860–3.

29. Abrams D. System of Ophthalmology - Ophthalmic Optics and Refraction. 1st edition. Duke-Elder SS, editor. The C.V. Mosby Company; 1970. 879 p.

30. Tong L, Saw S-M, Chia K-S, Tan D. Anisometropia in Singapore school children. Am J Ophthalmol. 2004 Mar;137(3):474–9.

31. Smith EL, Hung LF, Harwerth RS. Developmental visual system anomalies and the limits of emmetropization. Ophthalmic Physiol Opt J Br Coll Ophthalmic Opt Optom. 1999 Mar;19(2):90–102.

32. Abrahamsson M, Fabian G, Sjöstrand J. Refraction changes in children developing convergent or divergent strabismus. Br J Ophthalmol. 1992 Dec;76(12):723–7.

33. Smith EL, Hung LF, Harwerth RS. Experimentally induced strabismus can produce anisometropia in young monkeys. Invest Ophthalmol Vis Sci. 1994;35:1951.

34. Ingram RM, Gill LE, Lambert TW. Emmetropisation in normal and strabismic children and the associated changes of anisometropia. Strabismus. 2003 Jun;11(2):71–84.

35. Stigmar G, Crawford JS, Ward CM, Thomson HG. Ophthalmic sequelae of infantile hemangiomas of the eyelids and orbit. Am J Ophthalmol. 1978 Jun;85(6):806–13.

36. Miller-Meeks MJ, Bennett SR, Keech RV, Blodi CF. Myopia induced by vitreous hemorrhage. Am J Ophthalmol. 1990 Feb 15;109(2):199–203.

37. Schaffer DB, Quinn GE, Johnson L. Sequelae of arrested mild retinopathy of prematurity. Arch Ophthalmol Chic Ill 1960. 1984 Mar;102(3):373–6.

38. Page JM, Schneeweiss S, Whyte HE, Harvey P. Ocular sequelae in premature infants. Pediatrics. 1993 Dec;92(6):787–90.

39. Wick B, Westin E. Change in refractive anisometropia in presbyopic adults wearing monovision contact lens correction. Optom Vis Sci Off Publ Am Acad Optom. 1999 Jan;76(1):33–9.

40. Beekhuis WH, van Rij G, Eggink FA, Vreugdenhil W, Schoevaart CE. Contact lenses following keratoplasty. CLAO J Off Publ Contact Lens Assoc Ophthalmol Inc. 1991 Jan;17(1):27–9.

41. Duling K, Wick B. Binocular vision complications after radial keratotomy. Am J Optom Physiol Opt. 1988 Mar;65(3):215–23.

42. Georgaras SP, Neos G, Margetis SP, Tzenaki M. Correction of myopic anisometropia with photorefractive keratectomy in 15 eyes. Refract Corneal Surg. 1993 Apr;9(2 Suppl):S29–34.

43. Schipper I. Anisophoria after implantation of an intraocular lens. J - Am Intra-Ocul Implant Soc. 1985 May;11(3):290–1.

44. Vital-Durand F, Ayzac L. Tackling amblyopia in human infants. Eye Lond Engl. 1996;10 (Pt 2):239–44.

45. Ingram RM. Refraction as a basis for screening children for squint and amblyopia. Br J Ophthalmol. 1977 Jan;61(1):8–15.

46. Birch E, Stager D, Everett M. Natural history of infantile anisometropia. Invest Ophthalmol Vis Sci. 1995;36:S45.

47. Rutstein RP, Corliss D. Relationship between anisometropia, amblyopia, and binocularity. Optom Vis Sci Off Publ Am Acad Optom. 1999 Apr;76(4):229–33.

48. Scheiman MM, Hertle RW, Beck RW, Edwards AR, Birch E, Cotter SA, et al. Randomized trial of treatment of amblyopia in children aged 7 to 17 years. Arch Ophthalmol Chic Ill 1960. 2005 Apr;123(4):437–47.

49. Wick B, Wingard M, Cotter S, Scheiman M. Anisometropic amblyopia: is the patient ever too old to treat? Optom Vis Sci Off Publ Am Acad Optom. 1992 Nov;69(11):866–78.

50. Duke-Elder SS. The practice of refraction. St. Louis; 1963.

51. Dwyer P, Wick B. The influence of refractive correction upon disorders of vergence and accommodation. Optom Vis Sci Off Publ Am Acad Optom. 1995 Apr;72(4):224–32.

52. Peters HB. The influence of anisometropia on stereosensitivity. Am J Optom Arch Am Acad Optom. 1969 Feb;46(2):120–3.

53. Blumenfeld D, Weakley D, Dias C. The effects of anisometropia on stereopsis and bifixation. Invest Ophthalmol Vis Sci. 1995;(36):S46.

54. Brooks SE, Johnson D, Fischer N. Anisometropia and binocularity. Ophthalmology. 1996 Jul;103(7):1139–43.

55. Ong J, Burley WS. Effect of induced anisometropia on depth perception. Am J Optom Arch Am Acad Optom. 1972 Apr;49(4):333–5.

56. Flom MC, Neumaier RW. Prevalence of amblyopia. Public Health Rep. 1966 Apr;81(4):329–41.

57. Palimeris G, Chimonidou E, Nikolakis S, Velissaropoulos P. Some clinical aspects concerning microtropia. Ann Ophthalmol. 1975 Oct;7(10):1343–8.

58. Weakley DR, Birch E, Kip K. The role of anisometropia in the development of accommodative esotropia. J AAPOS Off Publ Am Assoc Pediatr Ophthalmol Strabismus Am Assoc Pediatr Ophthalmol Strabismus. 2001 Jun;5(3):153–7.

59. Cruz AA, Bauer J, Held R. Inhibition of binocular contrast sensitivity in hypermetropic anisometropia. Optom Vis Sci Off Publ Am Acad Optom. 1991 Oct;68(10):819–20.

60. Mayer DL, Fulton AB. Preferential looking grating acuities of infants at risk of amblyopia. Trans Ophthalmol Soc U K. 1985;104 (Pt 8):903–11.

61. Mayer DL, Fulton AB, Hansen RM. Preferential looking acuity obtained with a staircase procedure in pediatric patients. Invest Ophthalmol Vis Sci. 1982 Oct;23(4):538–43.

62. Friendly DS, Jaafar MS, Morillo DL. A comparative study of grating and recognition visual acuity testing in children with anisometropic amblyopia without strabismus. Am J Ophthalmol. 1990 Sep 15;110(3):293–9.

63. Grosvenor T. Primary care optometry. In: Primary care optometry. 5th ed. Butterworth Heinemann Elsevier; 2007.

64. Weakley DR. The association between nonstrabismic anisometropia, amblyopia, and subnormal binocularity. Ophthalmology. 2001 Jan;108(1):163–71.

65. Grosvenor T. primary care optometry. In: Primary care optometry. 5th ed. Butterworth Heinemann Elsevier; 2007. p. 269–70.

66. Donders F. On the anomalies of accommodation and refraction of the eye. In: On the anomalies of accommodation and refraction of the eye. London: New Sydenham Society; 1864.

67. Bannon R. Clinical manual of aniseikonia. In: Clinical manual of aniseikonia. Buffalo,NY: American Optical Co; 1954. p. 100.

68. Bradley A, Rabin J, Freeman RD. Nonoptical determinants of aniseikonia. Invest Ophthalmol Vis Sci. 1983 Apr;24(4):507–12.

69. Rabin J, Bradley A, Freeman RD. On the relation between aniseikonia and axial anisometropia. Am J Optom Physiol Opt. 1983 Jul;60(7):553–8.

70. Kramer P, Shippman S, Bennett G, Meininger D, Lubkin V. A study of aniseikonia and Knapp's law using a projection space eikonometer. Binocul Vis Strabismus Q. 1999;14(3):197–201.

71. Remole A. Anisophoria and aniseikonia. Part I. The relation between optical anisophoria and aniseikonia. Optom Vis Sci Off Publ Am Acad Optom. 1989;66:659–70.

72. Remole A. Anisophoria and aniseikonia. Part II. The management of optical aniseikonia. Optom Vis Sci Off Publ Am Acad Optom. 1989;66:736–46.

73. Bannon R. Incidence o f clinically significant aniseikonia. Optom Vis Sci Off Publ Am Acad Optom. 1952;40:32–3.

74. Duke-Elder, Stewart W. Text-Book of Ophthalmology. St. Louis: CV- Mosby; 1949.

75. Burian HM, Walsh R, Bannon RE. Note on the incidence of clinically significant aniseikonia. Am J Ophthalmol. 1946 Feb;29:201–3.

76. Kulp MAT, Raasch TW, Polasky M. Chapter 32 - Patients with Anisometropia and Aniseikonia. In: BenjaminConsultant WJ, Borish IM, editors. Borish's Clinical Refraction (Second Edition) [Internet]. Saint Louis: Butterworth-Heinemann; 2006. p. 1479–508. Available from: http://www.sciencedirect.com/science/article/pii/B9780750675246500375

77. Wright LA, Cleary M, Barrie T, Hammer HM. Motility and binocularity outcomes in vitrectomy versus scleral buckling in retinal detachment surgery. Graefes Arch Clin Exp Ophthalmol Albrecht Von Graefes Arch Für Klin Exp Ophthalmol. 1999 Dec;237(12):1028–32.

78. Enoch JM, Schwartz A, Chang D, Hirose H. Aniseikonia, metamorphopsia and perceived entoptic pattern: some effects of a macular epiretinal membrane, and the subsequent spontaneous separation of the membrane. Ophthalmic Physiol Opt J Br Coll Ophthalmic Opt Optom. 1995 Jul;15(4):339–43.

79. Ogle KN. Induced size effect. Arch Ophthalmol. 1938;20:604–23.

80. Bannon R, Triller w. Anisiseikonia-a clinical report covering 10 year period. Am J Optom Arch Am Acad Optom. 1944;(31):173–82.

81. Remole A. Aniseikonia and fixation performance: effect of retinal stimulus location. Optom Vis Sci Off Publ Am Acad Optom. 1989 Mar;66(3):160–6.

82. Ogle KN. Researchers in binocular vision. Hafner Publishing Company.; 1950.

83. Scheiman M, Wick B, Steinman BA. Clinical Management of Binocular Vision: Heterophoric, Accommodative, and Eye Movement Disorders [Internet]. Lippincott Williams & Wilkins; 2002. Available from: https://books.google.sk/books?id=U6V6M1U1iScC

84. Brecher GA. A new method for measuring aniseikonia. Am J Ophthalmol. 1951 Jul;34(7):1016–21.

85. McCormack G, Peli E, Stone P. Differences in tests of aniseikonia. Invest Ophthalmol Vis Sci. 1992 May;33(6):2063–7.

86. Kehler LAF, Fraine L, Lu P. Evaluation of the aniseikonia inspector version 3 in school-aged children. Optom Vis Sci Off Publ Am Acad Optom. 2014 May;91(5):528–32.

87. Antona B, Barra F, Barrio A, Gonzalez E, Sanchez I. Validity and repeatability of a new test for aniseikonia. Invest Ophthalmol Vis Sci. 2007 Jan;48(1):58–62.

88. Optometry Updates: Aniseikonia Inspector [Internet]. [cited 2015 Jul 31]. Available from: http://optometry-updates.blogspot.sk/2006/04/aniseikonia-inspector.html

89. Aniseikonia Inspector additional info [Internet]. [cited 2015 Jul 31]. Available from: http://www.opticaldiagnostics.com/products/ai/additional_info.html

90. Rutstein RP, Corliss DA, Fullard RJ. Comparison of aniseikonia as measured by the aniseikonia inspector and the space eikonometer. Optom Vis Sci Off Publ Am Acad Optom. 2006 Nov;83(11):836–42.

91. space eikonometer - Hledat Googlem [Internet]. [cited 2015 Jul 31]. Available from: https://www.google.sk/search?q=space+eikonometer&client=safari&rls=en&source=lnms&tbm=isch&sa=X&ved=0CAcQ_AUoAWoVChMI7KCTurqFxwIVihIsCh1VvAMn&biw=1440&bih=799#imgrc=Yq4i-fujZU7fuM%3A

92. Polaski M. Aniseikonia cookbook. Columbus: Ohio state university; 1974.

93. What makes the SHAW lens different? Shaw Lens Inc. - Aniseikonia Solved [Internet]. [cited 2015 Jul 17]. Available from: http://shawlens.com/the_shaw_lens/the_science/

94. Remiasova M. Afocal magnifying lenses for M. Krasnansky. 2015.

95. De Wit GC. Evaluation of a new direct-comparison aniseikonia test. Binocul Vis Strabismus Q. 2003;18(2):87–94; discussion 94.

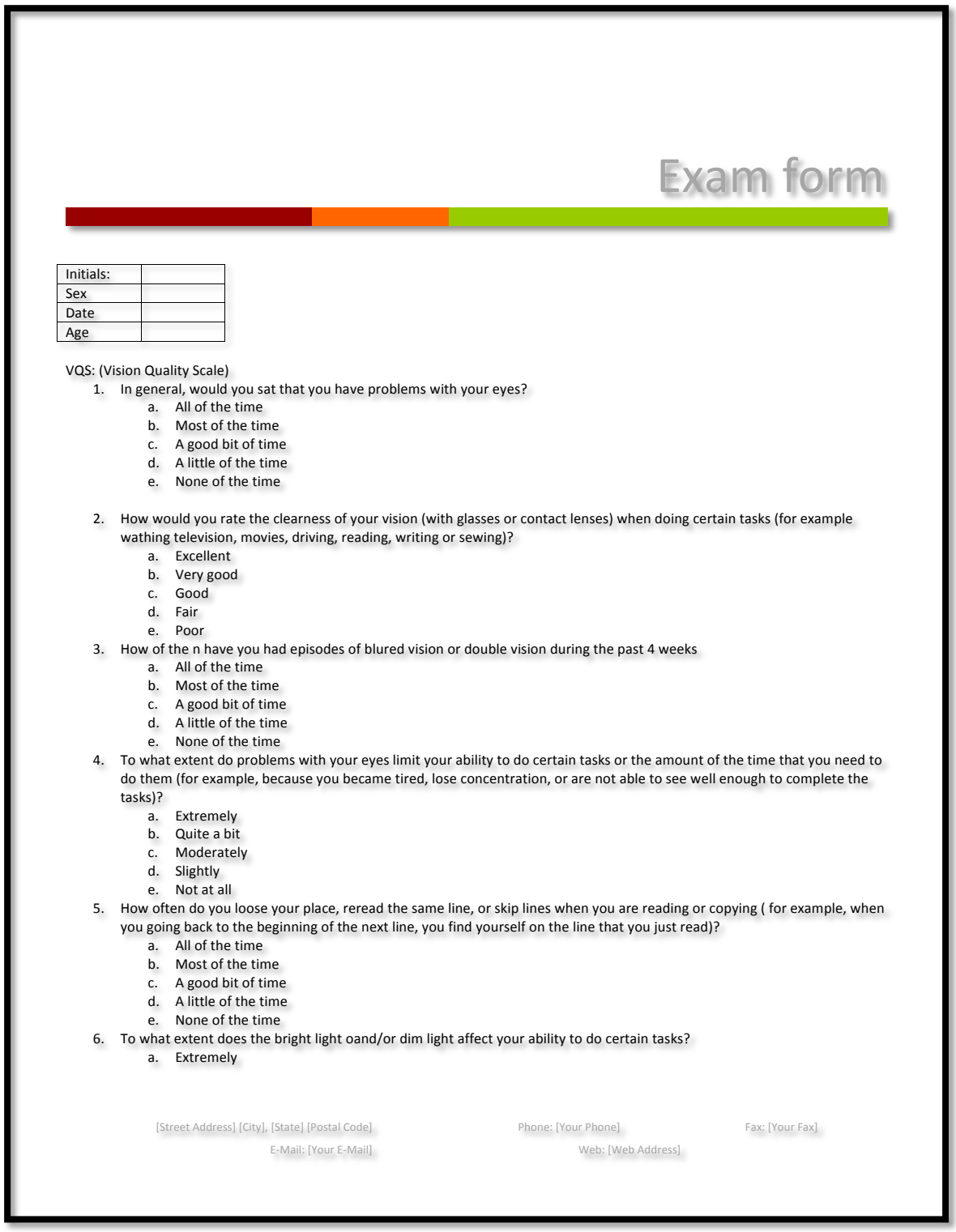
96. Fullard RJ, Rutstein RP, Corliss DA. The evaluation of two new computer-based tests for measurement of Aniseikonia. Optom Vis Sci Off Publ Am Acad Optom. 2007 Dec;84(12):1093–100.

11 List of Tables

12 List of Figures

13 Appendix

13.1 Exam form



Exam form

Initials:	
Sex	
Date	
Age	

VQS: (Vision Quality Scale)

1. In general, would you sat that you have problems with your eyes?
    a. All of the time
    b. Most of the time
    c. A good bit of time
    d. A little of the time
    e. None of the time

2. How would you rate the clearness of your vision (with glasses or contact lenses) when doing certain tasks (for example wathing television, movies, driving, reading, writing or sewing)?
    a. Excellent
    b. Very good
    c. Good
    d. Fair
    e. Poor
3. How of the n have you had episodes of blured vision or double vision during the past 4 weeks
    a. All of the time
    b. Most of the time
    c. A good bit of time
    d. A little of the time
    e. None of the time
4. To what extent do problems with your eyes limit your ability to do certain tasks or the amount of the time that you need to do them (for example, because you became tired, lose concentration, or are not able to see well enough to complete the tasks)?
    a. Extremely
    b. Quite a bit
    c. Moderately
    d. Slightly
    e. Not at all
5. How often do you loose your place, reread the same line, or skip lines when you are reading or copying (for example, when you going back to the beginning of the next line, you find yourself on the line that you just read)?
    a. All of the time
    b. Most of the time
    c. A good bit of time
    d. A little of the time
    e. None of the time
6. To what extent does the bright light oand/or dim light affect your ability to do certain tasks?
    a. Extremely

[Street Address] [City], [State] [Postal Code] Phone: [Your Phone] Fax: [Your Fax]
E-Mail: [Your E-Mail] Web: [Web Address]

13.2 Collected raw data

Patient no.	Initials	Questionnaire score:	Age	Sex	ARK SPH OD	ARK cyl OD	Keratometry OD	BCVA sph OD	BCVA cyl OD	ARK SPH OS
1	T.B	7	51	F	1	-0,5	8,02	1	0	1,25
2	A.B.	2	30	F	0,25	0	7,51	0,75	-0,25	0,5
3	J.G.	8	32	F	-0,5	0	7,73	0	0	-0,75
4	K.K.	13	24	F	0	-0,5	7,35	0	-0,25	0
5	M.K.	8	22	F	0,25	0,75	7,61	0,25	-0,25	-0,5
6	S.E.	1	26	M	-2,5	0	7,44	-2	0	-2,25
7	J.B.	4	27	F	2,5	0,25	7,68	2,75	0	3
8	L.S.	4	45	M	2,25	-0,5	7,8	2,25	0,5	1,5
9	T.R	7	59	F	1	0	7,76	1,25	0	1,25
10	Z.B.	4	33	F	-4,25	-0,5	7,68	-4,25	-0,5	-3,5
11	ML	7	50	M	0,5	0,75	8	0,5	-0,25	0,75
12	P.V.	6	45	M	0,5	0	7,82	0,75	0	0,5
13	A.L.	8	50	F	2,25	-0,75	7,52	2,5	-1	2,25
14	I.G.	1	20	F	-2	-0,5	7,57	-2,25	0	-2,5
15	M.K.	7	35	M	2,5	-2,75	8,07	2,25	-2,75	2,75
16	L.K.	6	49	F	0	0,25	7,36	-0,25	0	0

						-				
17	M.V.	6	29	F	-4	1,25	7,67	-3,75	-0,75	-4,5
18	V.B.	8	48	M	0,75	-0,5	7,44	0,25	0	0,25
19	Z.P.	3	50	F	1	0	7,84	1	0	1,25
20	J.B.	3	51	M	2	-0,5	8,26	2	-0,75	2
					-					
21	M.H.	7	34	M	0,75	-0,1	7,52	-0,5	-1,25	-1,5

ARK cyl OS	Keratometry OS	BCVA sph OS	BCVA cyl OS	Aniseikonia testing:	No size lens (%)	1,5% (%)	3%(%)	5%(%)	7%(%)
-0,5	7,95	1,25	-0,5		1	0	2	-1	5
-0,5	7,51	0,75	0		0	1	2	4	5
0	7,68	0	0		2	1	2	2	3
-									
0,25	7,39	-0,25	0		3	2	2	3	4
-0,5	7,62	0	0		-1	4	1	6	10
-									
1,25	7,37	-2	-1		1	1	2	1	2
0,25	7,67	3,25	0		-1	0	2	6	3
0,75	7,8	1,5	0,5		0	1	4	6	6
0	7,77	1,5			-2	2	4	4	6
-									
1,25	7,7	-3,5	0		0	-1	1	3	6
-0,5	8	1,25	-0,75		0	1	2	2	5
0	7,8	0,75	0		0	1	2	3	7
-									
0,75	7,47	2	-0,5		0	1	2	3	5
-0,5	7,48	-2,25	0		0	1	2	3	6
-3,5	8	2,25	-3		-1	-1	-3	-6	-1
-	7,36	-0,25	-0,25		0	-1	2	3	5

0,25								
-								
0,75	7,62	-4,5	0	0	0	1	3	6
0	7,37	1	0	1	2	3	5	6
0	7,83	1,25	0	-2	-2	-1	1	5
0	8,32	1,75	-0,25	1	2	4	5	5
-								
0,75	7,58	-1	-0,5	2	1	1	-1	-2

13.3 Whole statistical data (STATPLUS

Linear Regression

Regression Statistics

R	0,762
R Square	0,58
Adjusted R S	0,58
S	2,063
Total number	105

Response = 0,5848 * inserted size lens

ANOVA

	d.f.	*SS*	*MS*	*F*	*p-level*
Regression	1,	612,322	612,322	143,855	0,E+0
Residual	104,	442,678	4,257		
Total	105,	1 055,			

	Coefficients	*tandard Erro*	*LCL*	*UCL*	*t Stat*	*p-level*
Intercept	0					
serted size le	0,585	0,049	0,42	0,75	11,994	0,E+0
T (0,1%)	3,387					

LCL - Lower value of a reliable interval (LCL)
UCL - Upper value of a reliable interval (UCL)

Residuals

Observation	*Predicted Y*	*Residual*	*ndard Residuals*
1	0,E+0	1,	0,483
2	0,E+0	0,E+0	-0,002
3	0,E+0	2,	0,968
4	0,E+0	3,	1,452
5	0,E+0	-1,	-0,486
6	0,E+0	1,	0,483
7	0,E+0	-1,	-0,486
8	0,E+0	0,E+0	-0,002
9	0,E+0	-2,	-0,971
10	0,E+0	0,E+0	-0,002
11	0,E+0	0,E+0	-0,002
12	0,E+0	0,E+0	-0,002
13	0,E+0	0,E+0	-0,002
14	0,E+0	0,E+0	-0,002
15	0,E+0	-1,	-0,486
16	0,E+0	0,E+0	-0,002
17	0,E+0	0,E+0	-0,002
18	0,E+0	1,	0,483
19	0,E+0	-2,	-0,971
20	0,E+0	1,	0,483

21	0,E+0	2,	0,968
22	0,877	-0,877	-0,427
23	0,877	0,123	0,058
24	0,877	0,123	0,058
25	0,877	1,123	0,543
26	0,877	3,123	1,512
27	0,877	0,123	0,058
28	0,877	-0,877	-0,427
29	0,877	0,123	0,058
30	0,877	1,123	0,543
31	0,877	-1,877	-0,912
32	0,877	0,123	0,058
33	0,877	0,123	0,058
34	0,877	0,123	0,058
35	0,877	0,123	0,058
36	0,877	-1,877	-0,912
37	0,877	-1,877	-0,912
38	0,877	-0,877	-0,427
39	0,877	1,123	0,543
40	0,877	-2,877	-1,396
41	0,877	1,123	0,543
42	0,877	0,123	0,058
43	1,755	0,245	0,117
44	1,755	0,245	0,117
45	1,755	0,245	0,117
46	1,755	0,245	0,117
47	1,755	-0,755	-0,367
48	1,755	0,245	0,117
49	1,755	0,245	0,117
50	1,755	2,245	1,087
51	1,755	2,245	1,087
52	1,755	-0,755	-0,367
53	1,755	0,245	0,117
54	1,755	0,245	0,117
55	1,755	0,245	0,117
56	1,755	0,245	0,117
57	1,755	-4,755	-2,306
58	1,755	0,245	0,117
59	1,755	-0,755	-0,367
60	1,755	1,245	0,602
61	1,755	-2,755	-1,337
62	1,755	2,245	1,087
63	1,755	-0,755	-0,367
64	2,924	-3,924	-1,904
65	2,924	1,076	0,52
66	2,924	-0,924	-0,45